MULTIMEDIA UNIVERSITY ™

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 2, 2022/2023 (TERM ID 2220)**

## ETM4166 – RADIO NETWORK PLANNING TOWARDS 5G

(TE)

11 JULY 2023

9:00 A.M – 11:00 A.M.

(2 Hours)

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**INSTRUCTIONS TO STUDENT:**

1. This exam paper consists of **7 pages** (including cover page) with **3 questions**.
2. Attempt **ALL questions**. The breakdown of marks within each question is given.
3. Please write all your answers in the answer booklet provided. Show all relevant steps to obtain maximum marks

## Question 1

The following table gives the configuration for a WCDMA (3G) cell:

| | Notation | Unit | Downlink |
|---|---|---|---|
| Target load | $l$ | % | 80 |
| User bit rate | $R$ | kbps | 144 |
| Carrier frequency | $f_c$ | MHz | 1800 |
| | | | |
| **Transmitter** | | | |
| Max. power per connection | $P_t$ | Watt | 5 |
| TX antenna gain | $G_t$ | dBi | 13 |
| TX cable loss | $L_t$ | dB | 3 |
| TX antenna height | $h_b$ | m | 30 |
| | | | |
| **Receiver** | | | |
| Receiver noise figure | $F$ | dB | 6 |
| Required $E_b/N_0$ | $E_b/N_0$ | dB | 7 |
| RX antenna gain | $G_r$ | dBi | 1 |
| Antenna diversity gain | $G_d$ | dB | 2 |
| Soft handover gain | $G_{ho}$ | dB | 1 |
| RX antenna height | $h_m$ | m | 1.5 |
| | | | |
| **Other Margins and Gains** | | | |
| Cell edge location probability | $P_L$ | % | 90 |
| Shadow fading variance | $\sigma^2$ | dB | 36 |
| Body loss | $L_b$ | dB | 2 |
| Building penetration loss | $L_p$ | dB | 8 |

a) Find the maximum allowable path loss (MAPL). [15 marks]

b) Use the COST231-Hata model (refer to Table A.3 in the Appendix) to determine the cell range for the suburban environment.

[5 marks]

c) Briefly explain how the load on the network will impact the uplink coverage of a WCDMA network.

[2 marks]

**Continued...**

d) State TRUE or FALSE for each of the statements below about the differences between the WCDMA and LTE air interfaces:

| Statement | True/False |
|---|---|
| i) Only one frequency channel is used in WCDMA while LTE uses multiple frequency channels (or subcarriers). | |
| ii) Users are separated by code in WCDMA while LTE uses a combined time and frequency approach for supporting multiple users. | |
| iii) Soft handover is supported in WCDMA while in LTE only hard handover is supported. | |

[3 marks]

## Question 2

a) Explain the EPS bearer concept of the QoS in LTE.

[4 marks]

b) State TRUE or FALSE for each of the statements below about the core network elements in the LTE network:

| Statement | True/False |
|---|---|
| i) MME takes care of all control plane functions related to subscriber and session management. | |
| ii) Radio resource control and radio mobility management are performed in eNB. | |
| iii) PG-W is the mobility anchor point for inter-eNB handover and for inter-3GPP mobility. | |
| iv) Anchor point for sessions towards the external packet data networks is at the SG-W. | |
| v) HSS provides subscriber profile and authentication information | |

[5 marks]

**Continued...**

c) The design targets for the uplink of an LTE cell are given in the table below:

| Criteria | Target |
|---|---|
| Required cell edge throughput | 512 kbps |
| MIMO configuration | 1T2R |
| Required SINR (at cell edge) | -1.8 dB |
| Assigned number of resource blocks | 10 |
| MCS (or TBS) Index | 3 |
| Block error rate (BLER) | 10% |
| Receiver noise figure | 3 dB |
| G-factor (or minimum SIR) | -1 dB |
| Adjacent cell load | 70% |

i) Based on the Transport Block Size (TBS) table given in the Appendix, determine the expected data rate (in kbps) at the cell edge.

[3 marks]

ii) Find the required receiver sensitivity. (Note: power density of thermal noise is -174 dBm/Hz)

[4 marks]

iii) Suppose the system bandwidth is 20 MHz and all the users are equally scheduled with 10 physical RBs per user. The MCS indexes of the users are uniformly distributed in the range 3 to 7. Determine the total throughput of the system in terms of bits/s (assume 10% BLER).

[9 marks]

**Continued...**

## Question 3

a) Explain the Service-Based Architecture (SBA) concept of the 5G network.

[4 marks]

b) State TRUE or FALSE for each of the statements below about the core network functions of 5G:

| Statement | True/False |
|---|---|
| i) UPF acts as a gateway to connect the RAN to external networks. | |
| ii) SMF handles session management and establishment, allocates IP addresses to the UEs, facilitates roaming, and controls the UPF. | |
| iii) NSSAAF and NSSF manage registration, reachability, mobility, connection, and location services. | |
| iv) AMF in charge of Network Slicing. | |

[4 marks]

c) Consider a 5G NR with subcarrier spacing of 60 kHz and channel bandwidth of 100 MHz. Show that the number of available resource blocks (RBs) is 135. (Hint: For channel bandwidth of 100 MHz, the required guard band is 1370 kHz)

[4 marks]

d) Give four motivations for having multiple numerologies in 5G NR.

[4 marks]

e) Briefly describe two key technologies for improving the 5G NR coverage.

[4 marks]

**End of Paper**

## Appendix

Table A.1 Log-normal fading margin as a function of location probability at cell edge

| Location probability at the cell border, % | Lognormal fade margin, dB |
|---|---|
| 50 | $\sigma \times 0$ |
| 60 | $\sigma \times 0.25$ |
| 70 | $\sigma \times 0.52$ |
| 80 | $\sigma \times 0.84$ |
| 90 | $\sigma \times 1.28$ |
| 91 | $\sigma \times 1.34$ |
| 92 | $\sigma \times 1.4$ |
| 93 | $\sigma \times 1.48$ |
| 94 | $\sigma \times 1.55$ |
| 95 | $\sigma \times 1.64$ |
| 96 | $\sigma \times 1.75$ |
| 97 | $\sigma \times 1.89$ |
| 98 | $\sigma \times 2.05$ |
| 99 | $\sigma \times 2.33$ |

Table A.2 Transport block size table

| $I_{TBS}$ | $N_{PRB}$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | 6 | 10 | 15 | 25 | 50 | 75 | 100 |
| 0 | 152 | 256 | 392 | 680 | 1384 | 2088 | 2792 |
| 1 | 208 | 344 | 520 | 904 | 1800 | 2728 | 3624 |
| 2 | 256 | 424 | 648 | 1096 | 2216 | 3368 | 4584 |
| 3 | 328 | 568 | 872 | 1416 | 2856 | 4392 | 5736 |
| 4 | 408 | 696 | 1064 | 1800 | 3624 | 5352 | 7224 |
| 5 | 504 | 872 | 1320 | 2216 | 4392 | 6712 | 8760 |
| 6 | 600 | 1032 | 1544 | 2600 | 5160 | 7736 | 10296 |
| 7 | 712 | 1224 | 1800 | 3112 | 6200 | 9144 | 12216 |
| 8 | 808 | 1384 | 2088 | 3496 | 6968 | 10680 | 14112 |
| 9 | 936 | 1544 | 2344 | 4008 | 7992 | 11832 | 15840 |
| 10 | 1032 | 1736 | 2664 | 4392 | 8760 | 12960 | 17568 |
| 11 | 1192 | 2024 | 2984 | 4968 | 9912 | 15264 | 19848 |
| 12 | 1352 | 2280 | 3368 | 5736 | 11448 | 16992 | 22920 |
| 13 | 1544 | 2536 | 3880 | 6456 | 12960 | 19080 | 25456 |
| 14 | 1736 | 2856 | 4264 | 7224 | 14112 | 21384 | 28336 |
| 15 | 1800 | 3112 | 4584 | 7736 | 15264 | 22920 | 30576 |
| 16 | 1928 | 3240 | 4968 | 7992 | 16416 | 24496 | 32856 |
| 17 | 2152 | 3624 | 5352 | 9144 | 18336 | 27376 | 36696 |
| 18 | 2344 | 4008 | 5992 | 9912 | 19848 | 29296 | 39232 |
| 19 | 2600 | 4264 | 6456 | 10680 | 21384 | 32856 | 43816 |
| 20 | 2792 | 4584 | 6968 | 11448 | 22920 | 35160 | 46888 |
| 21 | 2984 | 4968 | 7480 | 12576 | 25456 | 37888 | 51024 |
| 22 | 3240 | 5352 | 7992 | 13536 | 27376 | 40576 | 55056 |
| 23 | 3496 | 5736 | 8504 | 14112 | 28336 | 43816 | 57336 |
| 24 | 3624 | 5992 | 9144 | 15264 | 30576 | 45352 | 61664 |
| 25 | 3752 | 6200 | 9528 | 15840 | 31704 | 46888 | 63776 |
| 26 | 4392 | 7480 | 11064 | 18336 | 36696 | 55056 | 75376 |

Table A.3 Path loss models

| Model | Expression | Remarks |
|---|---|---|
| Free space | $PL = -27.55 + 20\,log_{10}(f) + 20\,log_{10}(d)$ | $f$ is in MHz, $d$ is in m |
| Okumura-Hata | $PL = A + B\,log_{10}\,d + C$<br>where<br>$A = 69.55 + 26.16\log_{10} f - 13.82\log_{10} h_b - a(h_m)$<br>$B = (44.9 - 6.55\log_{10} h_b)$<br><br>Small and medium-size cities (urban)<br>$a(h_m) = (1.1\log_{10}(f) - 0.7)\,h_m - (1.56\log_{10}(f) - 0.8)$<br>$C = 0$<br>Metropolitan areas<br>$a(h_m) = \begin{cases} 8.29(\log_{10}(1.54h_m))^2 - 1.1 & f \le 200MHz \\ 3.2(\log_{10}(11.75h_m))^2 - 4.97 & f \ge 400MHz \end{cases}$<br>$C = 0$<br>Suburban environments<br>$a(h_m) = (1.1\log_{10}(f) - 0.7)\,h_m - (1.56\log_{10}(f) - 0.8)$<br>$C = -2[\log_{10}(f/28)]^2 - 5.4$<br>Rural area<br>$a(h_m) = (1.1\log_{10}(f) - 0.7)\,h_m - (1.56\log_{10}(f) - 0.8)$<br>$C = -4.78[\log_{10}(f)]^2 + 18.33\log_{10}(f) - 40.98$ | $f$ is in MHz, $d$ is in km, and antenna heights are in m |
| COST 231-Hata | $PL = A + B\log_{10}\,d + C$<br>where<br>$A = 46.3 + 33.9\log_{10} f - 13.82\log_{10} h_b - a(h_m)$<br>$B = (44.9 - 6.55\log_{10} h_b)$<br>$a(h_m) = (1.1\log_{10}(f) - 0.7)\,h_m - (1.56\log_{10}(f) - 0.8)$<br><br>$C$ = 0 dB in dense urban; -5 dB in urban; -10 dB in suburban; -17 dB in rural | $f$ is in MHz, $d$ is in km, and antenna heights are in m |